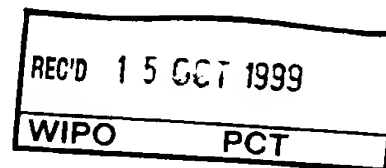


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TAASTRUP 08 October 1999

Karin Schlichting
Head Clerk

PEG-BASED MACROMONOMERS, CHEMICALLY INERT POLYMERS PREPARED
THEREFROM AND THE USE OF THESE POLYMERS FOR ORGANIC SYNTHESIS AND
ENZYME REACTIONS

5 FIELD OF THE INVENTION

The present invention relates to macromonomers containing ethylene glycol repeat units, to chemically inert polymers prepared therefrom and to the use of such polymers in solid phase biochemical assays.

10

BACKGROUND OF THE INVENTION

The use of acrylamide terminated polyethylene glycol in the preparation of cross-linked polymers has been described in International Patent Application No. WO 93/16118
15 and UK 9609911.4. Such polymers have a particular use as solid supports for the synthesis of peptides, oligonucleotides or oligosaccharides or as substrates for the immobilisation of proteins or as chromatographic resins. They are completely swelled in water and can also used for solid phase enzyme assays. Whilst the polymers so produced were particularly useful as supports for polypeptide synthesis the elimination
20 of the labile bonds in the backbone of the polymer matrix and replacement with more chemically inert bonds allow them to be used as supports for carrying out a large diversity of organic reactions.

Whereas all previously described PEG-based resins are quite labile to harsh and
25 generally used reaction conditions such as acetic anhydride and Lewis acid, thionyl

chloride, butyllithium or potassium hexamethyldisilazan, a polymer containing only stable primary ether bonds in addition to CH and CC bonds would be completely stable under those conditions.

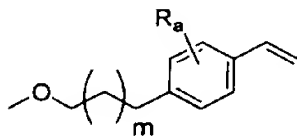
- 5 With the above requirements in mind we have now developed a series of macromonomers of oxethane or vinylphenylpropyl ether terminated polyethylene and polypropylene glycols from which cross-linked resins may be prepared in which the labile bonds in previously described PEG-based polymers are replaced by stable ether linkages whilst retaining the optimised balance of hydrophilic-hydrophobic character.

10

SUMMARY OF THE INVENTION

In one aspect the present invention concerns a macromonomer of polyethylene glycol having repeat units in the range 6-200 and having at least one end terminated by an

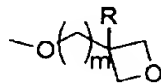
- 15 ether group having the formula:



where m is an integer of 0-10, a is an integer of 1-4, and

R is H or alkyl or aryl or arylalkyl;

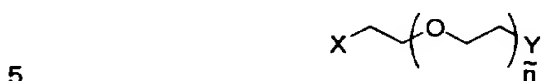
- 20 or having the formula



where m is an integer of 1-10, and

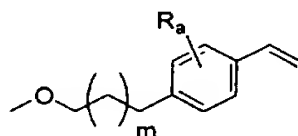
R is H or alkyl or aryl or arylalkyl.

In another aspect the present invention concerns a macromonomer of type A having the structure:



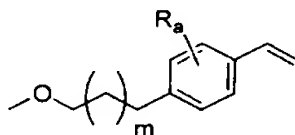
where \bar{n} is a real number of 6-300, and \bar{n} also means the average value of n in the following,

and where X and Y each independently is a group of the formula



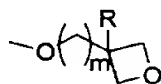
where m is an integer of 0-10, and R is H or alkyl or aryl or arylalkyl,

or where X is -OH, and Y is a group of the formula



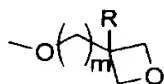
where m is 0-10, a is as defined above, and R is H or alkyl or aryl or arylalkyl,

or where X and Y each independently are a group of the formula



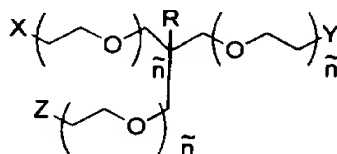
where m is 1-10, and R is H or alkyl or aryl or arylalkyl,

or where X is -OH, and Y is a group of the formula



5 where m is 1-10, and R is H or alkyl or aryl or arylalkyl.

In a further aspect the present invention concerns a macromonomer of type B having the structure:

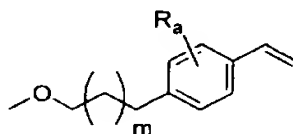


10

where R is H or alkyl or aryl or arylalkyl,

and n is a real number of 6-300 as defined above

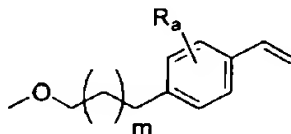
and where X, Y and Z each independently is OH or a group of the formula



15

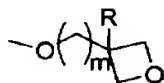
where m is an integer of 0-10, a is as defined above, and R is H or alkyl or aryl or arylalkyl,

provided that at least one of X, Y or Z is a group of the formula



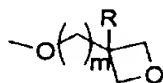
where m is an integer of 0-10, a is as defined above, and R is H or alkyl or aryl or arylalkyl,

5 or where X, Y and Z each independently is are OH or a group of the formula



where m is an integer of 1-10, a is as defined above, and R is H or alkyl or aryl or arylalkyl,

10 provided that at least one of X, Y or Z is a group of the formula



where m is an integer of 1-10, a is as defined above, and R is H or alkyl or aryl or arylalkyl.

15

DETAILED DESCRIPTION OF THE INVENTION

In the present context, the term "alkyl" designates a 1-10 carbon atom aliphatic residue such as methyl, ethyl, propyl, isopropyl, butyl, isobutyl, sec.butyl, tert.butyl,

20 pentyl, hexyl, heptyl, octyl, nonyl or decyl. The term "arylalkyl" designates an aryl

group linked to a 1-5 carbon atom alkylene chain such as methylene, ethylene or propylene, and the aryl group therein may be of the of the monocyclic or dicyclic aromatic type including normal carbocyclic aromatic types such as phenyl, naphthyl and

biphenyl, as well as heterocyclic types such as pyridyl, bipyridyl, imidazolyl, triazolyl, pyrrolyl, bipyrrrolyl, thiazolyl and oxazolyl.

The factor "a" as applied to the substituent R indicates that R is present of the phenyl
5 ring a total of "a" times, and that each group R can be selected from the definition of R independently of the other groups R.

The factor "ñ" is as defined above a real number of 6-300 and designates the average number of the ethyleneoxy group in question present in the macromonomer.

10

The macromonomers of the invention may conveniently be prepared by reacting an alkali metal derivative, such as a lithium, sodium, potassium or cesium derivative, of the appropriate polyethylene glycol, preferably the sodium derivative, with the appropriate halo substituted, e.g. bromo, chloro or iodo substituted, or arylsulfonate
15 substituted, such as tosyl substituted, vinylphenylalkyl or oxetanylalkyl derivative to yield the corresponding vinylphenylalkyl or oxetanylalkyl capped polyethylene glycol.

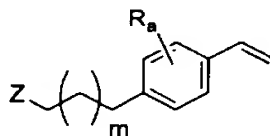
The polyethylene glycol may be of the "star" type provided by from tetra to hexa-branching of the macromonomer from e.g. an aromatic or aliphatic carbon atom
20 nucleus substituted with the PEG chains, or of the "T" shaped type where the PEG macromonomer is tri-branched from a tertiary or a quaternary carbon atom

The alkali metal derivative of polyethylene glycol with Li, Na, K or Cs may be formed by reaction with an alkali metal such as sodium, potassium, lithium or an alkali metal

hydride e. g. NaH, KH, LiH or by exchange with alkyl- or alkoxy- or other alkali metal salts e. g. BuLi, KOtBu, Cs₂CO₃, KHMDS.

The capped vinylphenylalkyl macromonomers may be polymerised by use of a free-radical initiator, such as an inorganic or organic peroxide, f.x. ammonium persulfate or t-butylperoxide or metachloroperbenzoic acid or AIBN, to yield a cross-linked resin. Similarly, the oxetanylalkyl capped macromonomers may be polymerised by the use of a cationic catalyst such as for example Et₂O:BF₃, TMSOTf, TfOH, TMSBr, TMSI, TiCl₄ or ZnBr₂ salts or halides and other salts of hafnium, yttrium, tantalum and iron to yield a cross-linked resin.

In yet a further aspect, the invention concerns a cross-linked polymer formed by the bulk polymerisation of the products of the reaction between mono- and di-alkali metal derivatives of polyethylene glycol with a vinylphenylalkyl derivative having the formula:

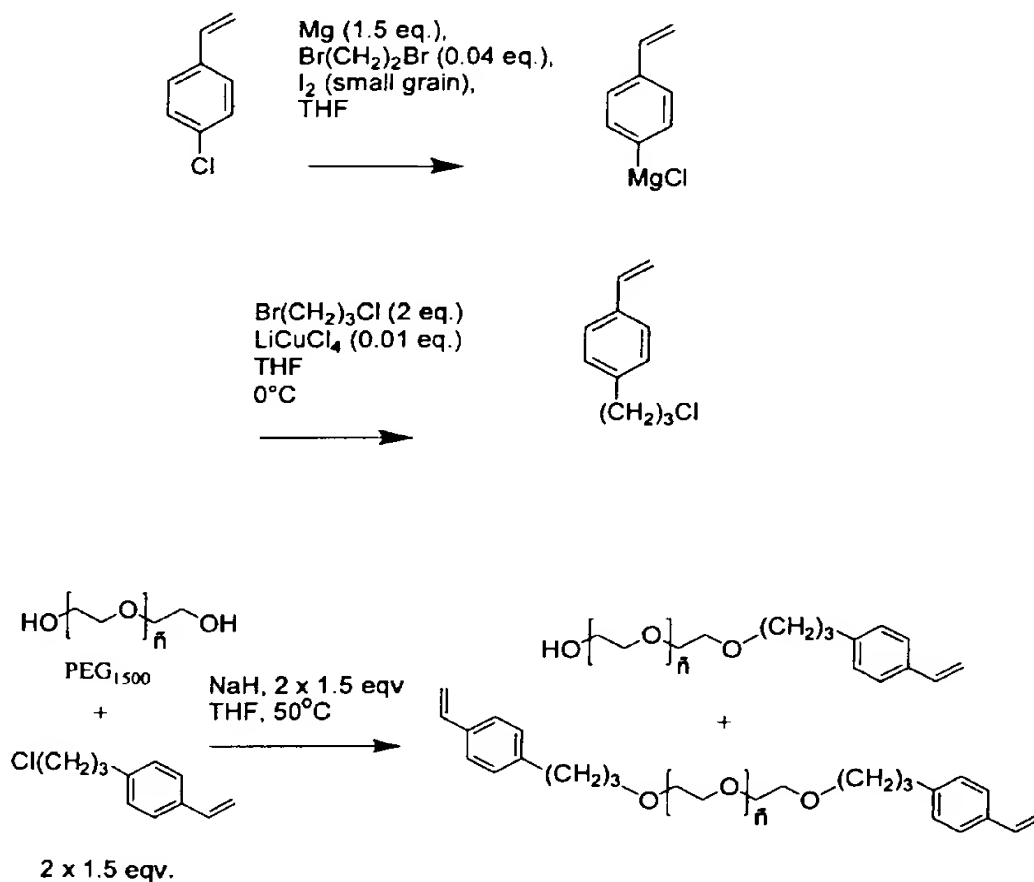


20

where Z is Cl, Br, I, toluenesulfonyloxy or CF₃SO₃,

a is an integer of 1-4, and m is an integer of 0-10, and R is H or alkyl or aryl or arylalkyl.

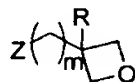
The synthesis of a compound of this class may for example be achieved in the following way:



5

In yet a further aspect the invention concerns a cross-linked polymer formed by the bulk polymerisation of the products of the reaction between mono- and di- alkali derivatives of polyethylene glycol with an oxetane or oxetanylmethyl derivative having

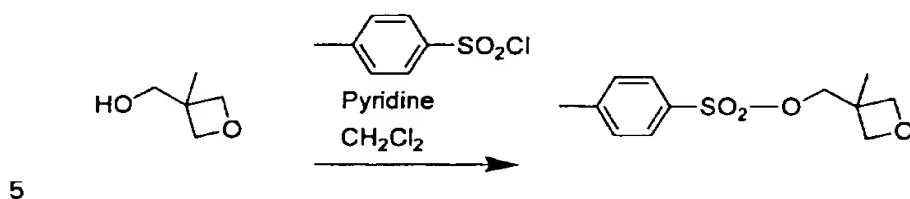
10 the formula:



where Z is Cl, Br, I, toluenesulfonyloxy or CF_3SO_3 .

m is an integer of 1-10, and R is H or alkyl or aryl or arylalkyl.

Members of this compound class may for example be prepared in the following manner:



In the drawings,

10 **Figure 1** is a schematic representation of the reactions involved in the preparation of vinylphenylalkyl ether capped polyethylene glycol and oxetane capped polyethylene glycol macromonomers.

Figure 2 is a representation of the cross-linked resin obtained by polymerisation of vinylphenylalkyl ether capped polyethylene glycol.

15 **Figure 3** is a representation of the resin obtained by the polymerisation of oxetane capped polyethylene glycol.

Figure 4 is a gel phase ^{13}C NMR trace of the cross-linked polymer of **Figure 2** derivatized by Fmoc-Gly.

Figure 5 is a magic angle spinning solid phase ^1H -NMR trace with selective irradiation at 3.67 ppm to suppress the PEG signal of the cross-linked polymer of Figure 2 after acylation with Fmoc-Gly. Resolved spectra were obtained and similar results were obtained with the resin in Figure 3 in MAS solid phase ^1H -NMR spectroscopy.

Figure 6 is a gel phase ^{13}C -NMR trace of the cross-linked polymer of Figure 3.

Figure 7 Shows organic reactions which have been successful on resin prepared by polymerization of 3-methyloxetan-3-ylmethyl derivatised macromonomers.

Figure 8 Illustrates a solid phase enzyme assay in which a fluorescence quenched substrate bound to a resin prepared from vinylphenylpropyl-PEG macromonomers is cleaved for 1 h by subtilisin Carlsberg migrating through the polymer network. The same result was obtained with the SPOCC polymer.

The following examples illustrate the present invention.

Example 1

3-Methyl-3-(4-toluenesulfonylmethyl)-oxetane. 4-Toluene sulfonyl chloride (20 g, 105 mmol) was dissolved in CH_2Cl_2 (50mL) and pyridine (50 mL). Under cooling in an ice bath, 3-hydroxymethyl-3-methyl-oxetane (100 mmol, 9.9mL) was added dropwise.

The reaction was warmed to room temperature over night. It was diluted with CH_2Cl_2 (100mL) and extracted with water. The organic phase was dried with magnesium sulfate filtered and solvents were removed by evaporation. The remainders were coevaporated several times with toluene to remove the remaining pyridine and with
5 chloroform to remove the toluene. The obtained crude product was of sufficient purity for further use. Yield: 22 g of a white crystalline solid (92 %). TLC: Rf (petroleum ether/ethyl acetate 1:1): 0.56. The spectroscopic data were in accordance with literature (Dale, J.; Fredriksen, S.B. *Act.Chem.Scand.B* 1992, 46, 271-277).

10

Example 2

Bis-oxytanylated polyethylene glycol (bis-(3-methyl-3-oxetanylmethoxy)-PEG.
Polyethylene glycol (-400 or -1500; 10 mmol) was dried carefully by coevaporation of water with toluene. Then it was dissolved in toluene and DMF (each 15 mL). Under
15 stirring potassium hexamethyldisilazan (KHMDs) (22 mmol) was added at room temperature, after 15 min the solvents were removed together with HMDS at 50 °C waterbath with the rotary evaporator. The remaining potassiated PEG was redissolved in DMF (15mL). The tosylated oxetane derivative (24 mmol) was added in portions at room temperature and the reaction was heated for 12 hrs to 75 °C. After cooling to
20 ambient temperature water (2mL) was added and stirred for 15 min in order to fully hydrolyze unreacted alkylating agent. The solvents were removed at 40 °C under reduced pressure. The remaining slurry was resuspended in CH_2Cl_2 and filtered through a layer of kieselguhr (Celite) (2 cm of kieselguhr on a glass filter, wetted with organic solvent and compressed) and finally evaporated to dryness. Yield: 90 % of 2a.

The NMR of the acetylated product indicated the alkylation of > 95 % of the PEG-hydroxy groups with oxetane rings.

When reduced excess of the alkylating reagents 3 was employed (15 and 18 mmol)
5 the percentage of oxetanyl group was decreased (66 %, 80 %).

Example 3

Acetylation of mixtures of mono- and bis-oxetanylated PEG .

10 Reaction mixture from Example 2 (10 g) was dissolved in pyridine (20mL). Acetic anhydride (10mL) was added and the reaction was stirred at room temperature for 24 h. Solvents were removed under reduced pressure and the degree of acetylation was quantified by ¹H-NMR.

15

Example 4

SPOCC-Resin formed by polymerization of oxetanylated PEG.

Procedure A.: Oxetanylated PEG-1500 or -400 (1 to 20 mmol) prepared as in Example 2 or the acetylated derivative from Example 3 was dissolved under argon in an equal
20 volume of CH₂Cl₂, cooled to -20 °C, and stirred with a magnetic stirrbar. Boron trifluoride diethyletherate (0.15 to 0.3 equiv.) was added. Warming was conducted gradually in order to determine the temperature at which polymerization occurs (-10 °C, 2 h; 0 °C, 2 h; 4 °C, 2 h). Finally, the viscosity of the solution increased and magnetic stirring stopped (sticky point). The sticky point was reached after the
25 solution was kept at 4 °C for 30 min. The polymer was stored at this temperature (2 d) and an additional day at room temperature. For work-up the polymer was cut into

pieces. These were swollen (CH_2Cl_2 , 2 h) and then granulated through a metal sieve (1 mm pore size) employing a pestle. The granulated resin was washed carefully (CH_2Cl_2 , THF, DMF, water, DMF, THF, CH_2Cl_2) and dried *in vacuo*.

Resin loading and the swelling volumes in different solvents were determined. The hydroxyl group capacity of the polymers was determined by esterification with fluorenylmethyloxycarbonyl (Fmoc)-Gly using the MSNT method (Tetrahedron Letters 1988, 29, 5871-5874) and measuring the UV-absorbance of the adduct of dibenzofulvene and piperidine formed by treatment of a weighted polymer sample with 20% piperidine/DMF. 0.6

- 10 The swelling capacity of the polymer product was determined by the syringe method (Azanneau, F.I., et al. J. Peptide Sci., 1995, 1, 31-44). The swelling volumes of the polymer was 11 mL/g in DMF; 12 mL/g in methylene dichloride and 14 mL/g in water respectively.

15

Example 5

SPOCC-Resin formed by polymerization of oxetanylated PEG. Procedure B.: Oxetanylated PEG-1500 from Example 3 was dissolved in CH_2Cl_2 (1 mL/g monomer) and cooled to 0 °C. Lewis acid catalyst BF_3OEt_2 was added (0.4 eq.). It was warmed to room temperature and the sticky point was reached after 10 min, as indicated by increased viscosity halting the magnetic stirrer. After stirring stopped the reaction was warmed to 60 °C for 2 d. After cooling to room temperature work-up was conducted as described under procedure A.

Example 6

SPOCC-Resin formed by polymerization of oxetanylated PEG.

Procedure C.: Oxetanylated PEG-400 from Example 2 was dissolved in diglyme (1mL/g
5 monomer) and stirred at room temperature. BF_3OEt_2 was added slowly and stirring
stopped after 1 min. The reaction was warmed to 70 ° for two d. After cooling to
room temperature work-up was conducted as described under procedure A.

Loadings and swelling obtained with resins prepared in Examples 4-6 are presented in
10 table 1 and it is clear that the best polymerization is obtained with acetylated
macromonomers.

Table 1.

| PEG Length | Oxetane (%) | -OR | Protocol | loading | swelling: H ₂ O | DMF | CH ₂ Cl ₂ |
|---------------|----------------|-----|----------|---------|-------------------------------|-----|---------------------------------|
| 400 | > 95 | -H | A | 0.6 | | | |
| 400 | >95 | -Ac | B | 0.4 | 2.6 | 2.3 | 3.3 |
| 400 | 70 | -Ac | B | 1.2 | | | |
| 1500 | >95 | -H | A | 0.4 | 43 | 37 | 54 |
| 1500 | >95 | -Ac | C | 0.3 | 10 | 8 | 13.5 |

Example 7

15

Bis-vinylphenylpropyl-polyethylene glycol(1500):

Anhydrous (Harris, J. M. J. Macromol. Sci., Rev. Macromol. Chem. Phys.

1985;C25:325-373.) PEG₁₅₀₀ (12.4 g) was dissolved in THF (25 mL) under Ar at

50°C and NaH (497 mg, 60% in oil, 1.5 eq.) was added. After 5 min.

Vinylphenylpropylchloride (2.2 mL, 1.5 eq.) was added over a period of 15 min.

Addition of NaH/vinylphenylpropylchloride (1.5 eq. each) was repeated after 3 h and again NaH (1.5 eq.) was added after 6 h. The brown mixture was stirred for another

5 16 h, concentrated, dissolved in water (75 mL), neutralized, water (125 mL) was added and the solution washed with light petroleum (50 mL). Concentration of the water phase and subsequent coevaporation with toluene (3x35 mL) gave a brown, opaque residue which was dissolved in CH_2Cl_2 (150 mL) and dried with MgSO_4 (35 g). Filtration through Celite and concentration to dryness yielded 13.1 g light brown solid
10 (94%), pure according to proton NMR.

Example 8

Polymerisation of *bis*-vinylphenylpropyl-polyethylene glycol(1500):

15 Resin from vinylphenylpropyl substituted PEG (1500) synthesized in Example 7 was prepared in beaded form by inverse suspension polymerisation of the vinylphenylpropyl substituted PEG (1500) (12.6 g) at 70°C for 2.5 h using $(\text{NH}_4)_2\text{S}_2\text{O}_8$ (148 mg, 0.07 eq.), tetramethyl ethylenediamine (443 μL , 0.32 eq), sorbitan monolaurate (133 mg) and a polymerization procedure described previously .(Auzanneau, F.-I.; Meldal, M.,
20 and Bock, K., J. Pept. Sci., 1995, 1, 31-44.) 120 g carbon tetrachloride and 80g n-heptane were mixed in a polymerizer and purged with nitrogen for twenty minutes and warmed to 70°C. A solution of the product from Example 7 (12.6 g) in 30 g water
together with 0.148 g $\text{K}_2\text{S}_2\text{O}_8$ was purged with nitrogen and poured into the organic phase and stirred at 650 rpm. After 2 min tetramethylethylene dianine (443 μL , 0.32
25 eq.) was added. Polymerisation was allowed to proceed for five hours at 70 °C at the

end of which time the reaction mixture was filtered, the beads washed with methanol and dried under vacuum. The dried particles were sized at 70-400 μm in diameter. Yield: 65%.

5

Example 9

Polymerisation of *bis*-vinylphenylpropyl-polyethylene glycol(1500):

Alternatively the resins were prepared by bulk polymerisation in water at r.t. for 24 h using $(\text{NH}_4)_2\text{S}_2\text{O}_8$ (0.06 eq.) and tetramethyl ethylenediamine (0.25 eq.) followed by
10 granulation, sieving, washing and lyophilization. Yields: 71%. The loading and swelling was determined as described in Example 4: Loading: 0.22 mmol/g. Swelling: 4 mL/g (DMF), 4 mL/g (H_2O), 6 mL/g (CH_2Cl_2)

Example 10

15

The macromonomers of the present invention can be co-polymerised with other monomers to vary the properties in the final polymer. The products from Example 7 can be co-polymerised with many monomers capable of free radical polymerisation, for example styrene, divinylbenzene, methacrylates, acrylates and acrylamides.
20 However, co-monomers for the macromonomer products of Example 7 are restricted to oxetane-containing monomers.

Example 11

25 **Macropolymers** of the type produced by the polymerisation of the macromonomers of Examples 2-3 and 7 are both expected to be chemically stable and inert, but to have

different respective physical properties. For example under hydrogenolitic, strongly basic or strongly acidic conditions both resins are fully stable. They have, however different preference for solvents of swelling. In contrast to previously reported PEG-based resins, the resins of the present invention are stable for extended periods of 5 time to thionylchloride, 6 N HCl, TMS-Br, TMS-OTf and Ac₂O, conc KOH, KHDMS/CH₂Cl₂ and 3 mM BuLi.

The main advantages of the polymers obtained from macromonomers of the present invention are the lack of functional groups such as amides in the polymer backbone, 10 high capacity, optimum hydrophilic/hydrophobic balance and high mechanical and in particular chemical stability. The polymers are cost-effective as they are readily prepared using available low-cost bio-compatible polyethylene glycols. The hydroxyl groups of the polymers are amenable to a wide range of functional group transformations without effecting the polymer backbone. The macropolymer resins 15 have an open structure that allow enzymes to penetrate into the interior of the polymer network under aqueous conditions. In addition to their excellent synthesis properties they are therefore suited for performing solid phase enzyme assays using fluorescence quenched substrates or a combination of fluorescence quenched substrates and inhibitors both attached to the polymer. In particular the resin can be 20 used in combinatorial organic synthesis of substrates and inhibitors by the split and combine method, followed by solid phase high throughput screening by exposure to enzymes and inspection of reaction development. The structure of the polymers provides excellent flow properties and reagent or solvent accessibility under organic reaction conditions.

25

The functional group modification is illustrated in the following examples where the hydroxyl groups are converted into bromides or amino groups.

Example 12

5

Bromo-SPOCC-resin

Resin from Example 4 (1 g, 0.6 mmol) was suspended in CH_2Cl_2 (10 mL).

Triphenylphosphine (787 mg, 5 eq.) and imidazol (204 mg, 5 eq.) were added. After complete dissolution it was cooled in a water bath to 10 °C and bromine was added

10 dropwise (155 μl , 5 eq.). Subsequently the water bath was removed and it was stirred over night at room temperature. The resin was filtered and washed with DMF, water, DMF, THF, and CH_2Cl_2 . Elemental analysis afforded a bromine content of 0.86 mmol/g resin.

15

Example 13

Amino-SPOCC-resin.

Resin from Example 4 (1 g, 0.6 mmol) was suspended in a solution of sodium azide in DMSO (390 mmol, 10 eq., 10 mL). The mixture was warmed to 60 °C for a period of

20 18 h. The resin was filtered and washed extensively with DMF, water and DMF.

Reduction was effected employing 1,4-dithio-threitol (DTT) in combination with 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) (10 mL of a 0.5 M solution of DTT in DMF,

containing 0.1 M of DBU). The resin was filtered and washed with DMF, THF, and

CH_2Cl_2 . Resin loading was determined by spectrophotometrical measurement of Fmoc-

cleavage after functionalization of a resin sample with Fmoc-succinimide (10 eq., 4 h).
Measured loading: 0.44 mmol/g.

- 5 The usefulness of the polymers obtained from the macromonomers of the present invention for organic synthesis and simultaneous compatibility with aqueous conditions are illustrated in the following examples:

Example 14

10

**p-[α -(*L*-Seryl-*L*-phenylalanyl-*L*-leucyl-glycylamido)-2,4-dimethoxy benzyl]-
phenoxyacetylamido-SPOCC-resin**

SPOCC-resin (210 mg, 0.1 mmol) was functionalized with the Fmoc-protected Rink-linker. (208 mg linker, 0.4 eq) was dissolved together with TBTU (122 mg, 0.38
15 mmol) and *N*-ethylmorpholine (NEM) (83 μ L, 0.5 mmol) in DMF (3 mL) and after 10 min added to the resin for 3 h. After washing with DMF (5 times) the Fmoc-group was cleaved (20 % piperidine in DMF, 2 and 16 min). The deprotected amine functionality was acylated with Fmoc-amino acids (3 eq. of Fmoc-Gly-OH, Fmoc-Leu-OH, Fmoc-Phe-OH, and Fmoc-Ser-OH) which were activated with TBTU (93 mg, 0.29 mmol) and
20 NEM (66 μ L, 0.4 mmol) as described for the linker and also coupled for 3 h each. After final Fmoc-deprotection the product was cleaved of a resin sample (2 mg, 95 % TFA, 2h) and analyzed by HPLC and MALDI-MS. r.t. = 24.0 min. MALDI-MS:

Calc. ($M = C_{20}H_{31}N_5O_5$). Found (MH^+ , MNa^+ , MK^+): 422 m/z, 444 m/z, 460 m/z. The final loading was 0.36 mmol/g.

Example 15

p-[α -(*N*-Oxalyl-*L*-phenylalanyl-*L*-leucyl-glycylamido)-2,4-dimethoxy benzyl]-phenoxyacetamid-SPOCC-resin.

- 5 The SPOCC-resin of Example 14 (200 mg, 0.072 mmol) was treated for 3 h with an aqueous solution of NaIO_4 (92 mg, 6 eq.) in sodium phosphate buffer (2.5 mL of 50 mmol NaH_2PO_4 , pH 7) resulting in a solution of ca. pH 5. The resin was filtered off, washed with water, DMF, THF, and CH_2Cl_2 and analyzed. HPLC: r.t. = 25.6 min.

MALDI-MS: Calc.(M = $\text{C}_{19}\text{H}_{26}\text{N}_4\text{O}_5$): 390.44. Found (MNa^+ , MH_2ONa^+): 413.3, 431.4

10 m/z.

Example 16

Reaction of aldehyde-resin with phenyl lithium.

- 15 The SPOCC-resin of Example 15 (30 mg, 0.011 mmol) was treated with a solution phenyllithium (7 eq. in 1mL THF, 10 min at 0 °C, followed by 1.5 h at room temperature. Analysis of the reaction afforded a mixture of several product in the range between 24 and 37 min of the HPLC. Products in the range between 24 and 27 min displayed the mass of the starting material. Products in the range between 31 and
- 20 37 min displayed the mass of dimers of the starting material. MALDI-MS: Calc.(2xM): 780.88). Found: ((2xM) Na^+): 804 m/z. No side-reactions were observed involving the resin itself.

Example 17

p-[α -(*N*-acryl-*L*-phenylalanyl-*L*-leucyl-glycylamido)-2,4-dimethoxy benzyl]-phenoxyacetamid-SPOCC.

- 5 Methyl triphenylphosphonium iodide (69 mg, 0.171 mmol) was suspended in THF (2 mL) and cooled to -50 °C. Butyl lithium (0.154 mmol) was added. The salt dissolved and the color of the solution changed to a strong yellow-orange. After 20 min the solution was warmed to -10 °C. Resin from Example 15 (96 mg, 0.034 mmol) was added under argon to the stirred solution and reacted for 2 h. Preparative cleavage of
- 10 the product (95 % TFA, 2 h) afforded a mixture of 2- and 3-hydroxypropionyl compounds. They were obtained through the hydration of the acrylamidic Wittig reaction product.

Example 18

15

***N*-(4-Carboxyl-but-2-*trans*-en-oyl)-(L)-leucyl-(L)-leucyl-glycyl-SPOCC-resin**

- Lyophilized resin from Example 15 (90 mg, 0.041 mmol) was treated with toluene (1 mL) and triethylorthoformate (0.5 mL) for two h and was washed with dry toluene (6x). Triethylphosphonoacetate (41 μ l, 5 eq.) was dissolved in toluene (1 mL). At 0 °C
- 20 butyllithium (4.5 eq.) was added. After 10 min the solution was added to the resin and reacted at ambient temperature for 90 min. After washing (DMF, THF, CH₂Cl₂) and drying the resulting resin was analyzed with MAS-solid phase NMR in CDCl₃.

- Cleavage of an analytical sample and HPLC-analysis was conducted. One portion of the resin (45 mg) was cleaved and isolated by preparative HPLC yielding the title
- 25 product (5.2 mg, 64 %). r.t. = 28.0 min. ¹H-NMR, 250 MHz, D₄-MeOD): δ = 0.88-

0.98 (m, 12 H, Leu-Me), 1.6-1.75 (m, 6 H, Leu), 3.8-4.0 (2d, 2 H, $^2J = 17.8$ Hz, Gly- α), 4.4-4.5 (m, 2 H, Leu- α), 6.68, 7.06 (2 d, 2 H, $^3J_{trans} = 15.5$ Hz, olefinic protons). ^{13}C -NMR, 60 MHz, D_4 -MeOD): $\delta = 131.9, 137.3$ (olefinic carbons). ES-MS: Calc.: M ($C_{18}H_{29}N_3O_7$) = 399.20. Found: 400.2 m/z.

5

The usefulness of the polymers for peptide and glycopeptide synthesis are illustrated in the following examples.

10

Example 19

***N*-(9-Fluorenyl-methoxycarbonyl)-L-alanyl-L-seryl-L-phenylalanyl-L-leucyl-glycyl-SPOCC-resin.**

SPOCC-400 (326 mg, 0.58 mmol/g loading, 0.19 mmol) from Example 4 was reacted
 15 twice with a solution of Fmoc-Gly-OH (339 mg, 3 eq.), MSNT (338 mg, 3 eq.), and *N*-methylimidazole (Melm) (68 μ l, 2.25 eq.) in CH_2Cl_2 (4 ml) each time for 45 min. After Fmoc-deprotection (20 % piperidine in DMF, 2 and 16 min) the glycyl-residue was elongated with four Fmoc-amino acids (3 eq. of Fmoc-Leu-OH, Fmoc-Phe-OH, Fmoc-Ser-OH, and Fmoc-Ala-OH) which were activated with TBTU (2.9 eq., 177 mg) and
 20 NEM (4 eq., 127 μ l). All acylation reactions were performed after 15 min of mixing time for the reagents in DMF (4 mL), a reaction time on the resin of 3 h, and followed by Fmoc-protection. After final Fmoc-deprotection the resin was analyzed with HPLC and MALDI-MS.

Example 20

N-(9-Fluorenyl-methoxycarbonyl)-*L*-alanyl-*O*-(2,3,4,6-tetra-*O*-acetyl- β -D-galactopyranosyl)-*L*-seryl-*L*-phenylalanyl-*L*-leucyl-glycyl-SPOCC-resin.

- 5 Resin from Example 19 (100 mg, 0.04 mmol) was lyophilized from dry toluene (3 mL) in a speed vac over night. Tetra-*O*-acetyl- α -D-galactopyranosyl trichloroacetimidate (0.12 mmol, 3 eqv.) was dissolved in CH_2Cl_2 (1.5 mL) and added to the resin. Under argon trimethylsilyl trifluoromethanesulfonate (TMSOTf) (120 μL of a 1 M solution in CH_2Cl_2) is added and reacted for one hour. The resin is then filtered off, washed with
- 10 CH_2Cl_2 , THF, DMF, THF, and CH_2Cl_2 , and dried *in vacuo*.

The glycosylation procedure was repeated. Analysis is conducted with HPLC and MALDI-MS after cleavage with NaOMe in MeOH (0.02 M, 2 h). Complete glycosylation had been achieved. HPLC: r.t. = 20.1 min. MALDI-MS: Calc: $\text{M}(\text{C}_{29}\text{H}_{45}\text{N}_5\text{O}_{12})$: 655.7 Da. Found (MNa^+): 656 m/z.

15

Example 21

L-Alanyl-*O*-(β -D-galactopyranosyl)-*L*-seryl-*L*-phenylalanyl-*L*-leucyl-glycinehydrazid

- Resin from Example 20 (2 mg, 0.035 mmol) is treated for 2 h with 20 % hydrazine in
- 20 water. HPLC: r.t. = 22.0 min. MALDI-MS: Calc.: $\text{M}(\text{C}_{29}\text{H}_{47}\text{N}_7\text{O}_{11})$: 669.7 Da. Found (MNa^+): 694 m/z.

The usefulness of the resins for enzyme reactions are illustrated in the following examples.

25

Example 22

***L*-Alanyl-(3-nitro)-*L*-tyrosinyl-*L*-glycyl-*L*-prolinyl-*L*-leucyl-glycyl-*L*-leucyl-*L*-tyrosinyl-alanyl-arginyl-(*N*^ε-2-aminobenzoyl)-*L*-lysiny-glycyl-glycyl-SPOCC-resin**

- 5 SPOCC-1500 from Example 3 (65 mg, 0.027 mmol) was treated twice with a solution of Fmoc-Gly-OH (41 mg, 5 eq.), MSNT (40 mg, 5 eq.), and Melm (8 μ L, 3.75 eq.) in CH₂Cl₂ (4 mL) for 45 min. The resin was filtered off and washed with CH₂Cl₂ and DMF. The Fmoc-group was cleaved (20 % piperidine in DMF, 2 and 16 min) and it was again washed with DMF. The fully protected nonapeptide of the sequence Fmoc-
- 10 A(NO₂)YGPLGL('Bu)YA(Pmc)R(Boc-Abz)KG-OH (43 mg, 3 eq.) was dissolved in DMF (4 mL) together with TBTU (6.8 mg, 2.9 eq.) and NEM (3.7 μ L, 4 eq.). After 15 min the latter solution was added to the resin and reacted for 3 h. The resin was extensively washed with DMF and treated twice with 95% TFA (10 min, 2.5 h) to remove side chain protecting groups. Subsequently the resin was washed with 95%
- 15 acetic acid (4 times 5 min), 5% triethylamine in DMF (three times 2 min), DMF (twice 2 min), THF, and CH₂Cl₂, followed by drying *in vacuo*. The peptide was cleaved off the resin with .1M NaOH for 2 h for analysis. HPLC: r.t. = 32.0 min. MALDI-MS: Calc. M(C₆₆H₉₉N₁₉O₁₉) = 1486.7 Da. Found: (MH⁺, MNa⁺-H₂O) 1487, 1493 m/z.

20

Example 23

Enzymatic cleavage of decapeptide bound to SPOCC-resin from Example 22. I.

- Subtilisin: The resin (2 mg) was treated with a solution of subtilisin (10⁻⁷ M) in pH 7 phosphate buffer (50 mmol NaH₂PO₄ in H₂O). After 15 min strong fluorescence under
- 25 a UV-irradiation was observed. After three h the resin was washed (water, DMF, THF, CH₂Cl₂) and dried. One portion of the enzyme-treated resin (1 mg) was treated with

NaOH (50 μ L of a 0.1 M solution, 2 h) and the product analyzed by HPLC followed by mass spectrometry. The other portion of the resin (1 mg) was subjected to Edman degradation. The HPLC indicated complete cleavage of the starting peptide substrate.

HPLC: r.t. = 22.0 min. MALDI-MS: Calc. $M(C_{26}H_{42}N_{10}O_7) = 606.7$ Da. Found: 617.6

5 m/z. Edman-degradation (3 cycles): A, Abz-; R-; K-.

II. Matrix-metalloprotease-9: The resin (2 mg) was treated with a solution of MMP-9 (100 nM and 275 nM) in pH 7.72 buffer (buffer 17, obtained from CCB, Ballerup) for 24 h. In both cases no significant fluorescence was observed. Cleavage and HPLC-analysis as described under I. yielded exclusively the starting peptide substrate.

10

Example 24

***L*-Alanyl-(3-nitro)-*L*-tyrosinyl-*L*-glycyl-*L*-prolinyl-*L*-leucyl-glycyl-*L*-leucyl-*L*-tyrosinyl-**

15 ***alanyl*-arginyl-(*N*^ε-2-aminobenzoyl)-*L*-lysiny-glycyl-glycyl-POEPS3-resin**

The resin obtained in Example 8 from mono- and bis-vinylphenylpropyl-PEG(1500) (0.1g, 0.02 mmol) was packed in a manual syringe synthesizer connected to a vacuum manifold and was esterified with Fmoc-Gly-OH using the MSNT procedure (Tetrahedron Letters 1988, 29, 5871-5874). The Fmoc group was removed with 20%

20 piperidine in DMF and the protected substrate Fmoc-

AY(NO₂)GPLGLY(tBu)R(Pmc)K(Boc-Abz)G-OH (45 mg, 1 eqv.) was coupled to the resin using in situ activation with TBTU (1 eqv.) and NEM (1 eqv.). The resin was

washed with DMF and dichloromethane and dried and protecting groups were

removed during 2 h with 95% aq TFA. The resin was washed with dichloromethane

25 and dried. The contents of amino acids were determined by quantitative amino acid analysis and Edman degradation sequence analysis and the expected sequence and

amount was found. The peptide was cleaved off the resin with 0.1M NaOH for 2 h for analysis. HPLC: r.t. = 32.0 min. MALDI-MS: Calc. $M(C_{68}H_{99}N_{19}O_{19}) = 1486.7$ Da. Found: $(MH^+, Mna^+ \cdot H_2O)$ 1487 m/z.

5

Example 25

Enzymatic cleavage of decapeptide bound to POEPS3-resin from Example 24. The resin from Example 24 (10 mg) was suspended in aqueous 50 mM bicine buffer (0.2 mM $CaCl_2$, pH 8.5, 100 μ L) and 10^{-6} M subtilisin Carlsberg (10 μ L) in the same buffer 10 was added. The reaction was followed visually under a fluorescence microscope (ex 320 nm; em 420-500 nm) and the reaction was complete in 60 min. Edman sequence analysis of the residual peptide on the resin showed the cleavage to be complete. The result was confirmed by cleavage with 0.1 M NaOH and HPLC analysis.

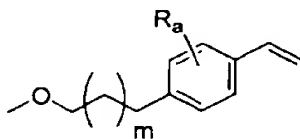
A similar experiment with the much larger MMP9 showed little cleavage only at the 15 resin surface indicating the importance of matching the length of the PEG used for the resin preparation with the size of the enzyme to be investigated. Cleavage with 0.1 M NaOH and HPLC analysis as in Example 23 showed only non cleaved peptide.

20

25

CLAIMS:

1. A macromonomer of polyethylene glycol having repeat units in the range 6-300 and having at least one end terminated by an ether group having the formula:

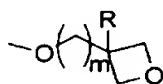


5

where m is an integer of 0-10, a is an integer of 1-4, and

R is H or alkyl or aryl or arylalkyl;

or having the formula

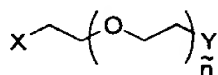


10

where m is an integer of 1-10, and

R is H or alkyl or aryl or arylalkyl.

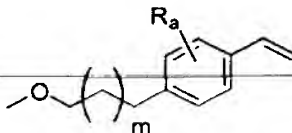
2. A macromonomer having the structure:



15

where \bar{n} is a real number of 6-300,

and where X and Y each independently is a group of the formula

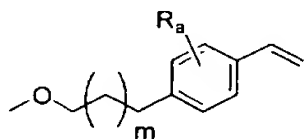


20

where a is an integer of 1-4, m is an integer of 0-10, and R is H or alkyl

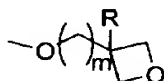
or arylalkyl,

or where X is -OH, and Y is a group of the formula



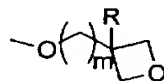
- 5 where a is an integer of 1-4, m is 0-10, a is as defined above, and R is H or alkyl or aryl or arylalkyl,

or where X and Y each independently are a group of the formula



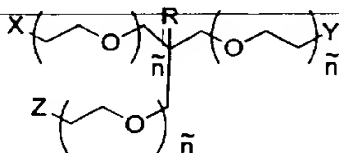
- 10 where m is an integer of 1-10, and R is H or alkyl or aryl or arylalkyl,

or where X is -OH, and Y is a group of the formula



- 15 where m is an integer of 1-10, and R is H or alkyl or aryl or arylalkyl.

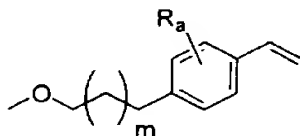
3. A macromonomer having the structure:



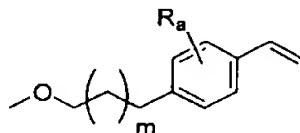
- 20 where R is H or alkyl or aryl or arylalkyl,

and \bar{n} is a real number of 6-300 as defined above

and where X, Y and Z each independently is OH or a group of the formula

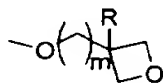


- 5 where a is an integer of 1-4, m is an integer of 0-10, a is as defined above, and R is H or alkyl or aryl or arylalkyl, provided that at least one of X, Y or Z is a group of the formula



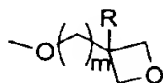
- 10 where a is an integer of 1-4, m is an integer of 0-10, a is as defined above, and R is H or alkyl or aryl or arylalkyl,

or where X, Y and Z each independently is are OH or a group of the formula



- 15 where m is an integer of 1-10, a is as defined above, and R is H or alkyl or aryl or arylalkyl,

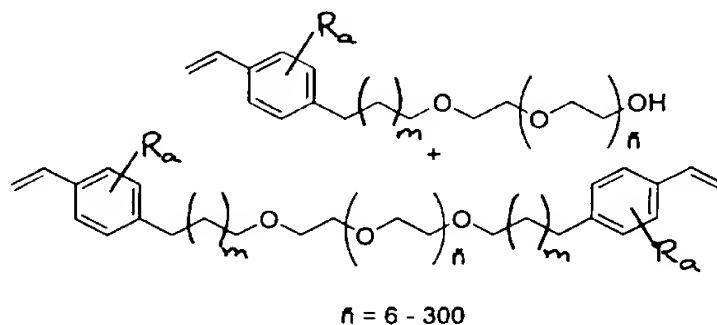
provided that at least one of X, Y or Z is a group of the formula



20

where m is an integer of 1-10, a is as defined above, and R is H or alkyl or aryl or arylalkyl.

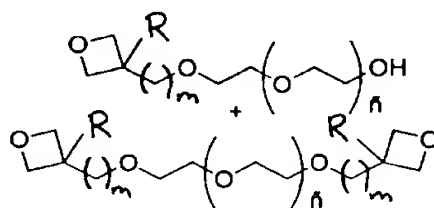
4. A macromonomer according to claim 2 which is terminated by a vinylphenylpropyl group and has the formula:



where R , and m are as defined in claim 1.

10

5. A macromonomer according to claim 2 which is terminated by an 3-methyloxetan-3-ylmethyl ether group and has the formula:



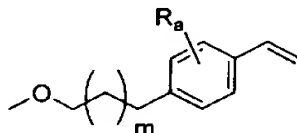
15

where $\bar{n} = 6-300$

where R and m are as defined in claim 1.

6. A macromonomer according to claim 5, which has been acetylated or in other ways temporarily hydroxyl-protected on free hydroxyl groups.

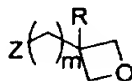
7. A process for the preparation of the macromonomers of claims 1 or 2 comprising
5 reacting an alkali metal derivative of a polyethylene glycol having 6-300 repeating units with a halo substituted compound having the formula:



where Z is Cl, Br, I, toluenesulfonyloxy or CF_3SO_3

10 and where a is an integer of 1-4, m is 0-10 and R is H or alkyl or aryl or arylalkyl

or having the formula

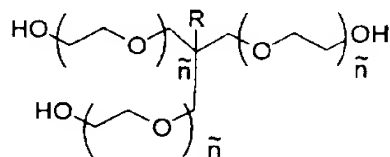


15

where Z is Cl, Br, I, toluenesulfonyloxy or CF_3SO_3

and where m is an integer of 1-10, and R is H or alkyl or aryl or arylalkyl

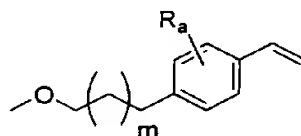
8. A process for the preparation of the macromonomer of claim 3 comprising reacting
20 an alkali metal derivative of a polyethylene glycol having the formula: -



where R is H or alkyl or aryl or arylalkyl and \tilde{n} is 6-300

with a halo substituted compound having the formula:

5



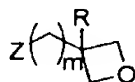
where Z is Cl, Br, I, toluenesulfonyloxy or CF_3SO_3

and where a is an integer of 1-4, m is 0-10, and R is H or alkyl or aryl or

10

arylalkyl

or having the formula



where Z is Cl, Br, I, toluenesulfonyloxy or CF_3SO_3

15

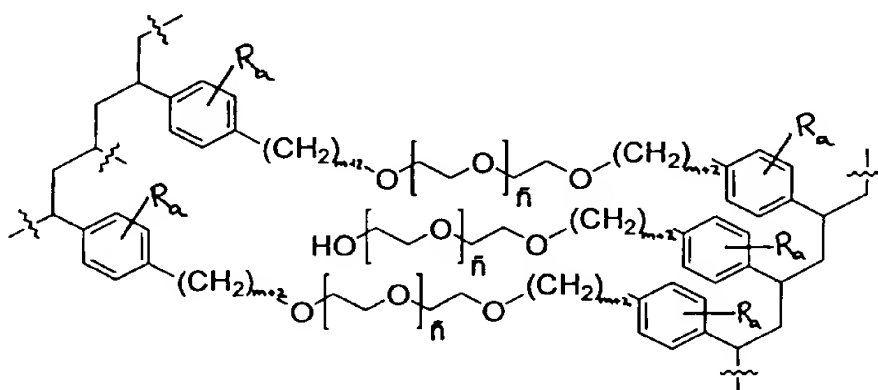
and where m is 1-10 and R is H or alkyl or aryl or arylalkyl

9. A process according to claims 7 or 8 wherein the alkali metal derivative is a sodium derivative.

20 10. A process according to claims 7 or 8 wherein the alkali metal derivative is a potassium derivative.

11. A cross linked polymer formed by the polymerisation of a macromonomer according to claim 2.

- 5 12. A cross linker polymer according to claim 11 wherein the macromonomer has the structure as claimed in claim 4, the polymerisation being initiated by a free radical catalyst and the polymer structure is represented as follows:

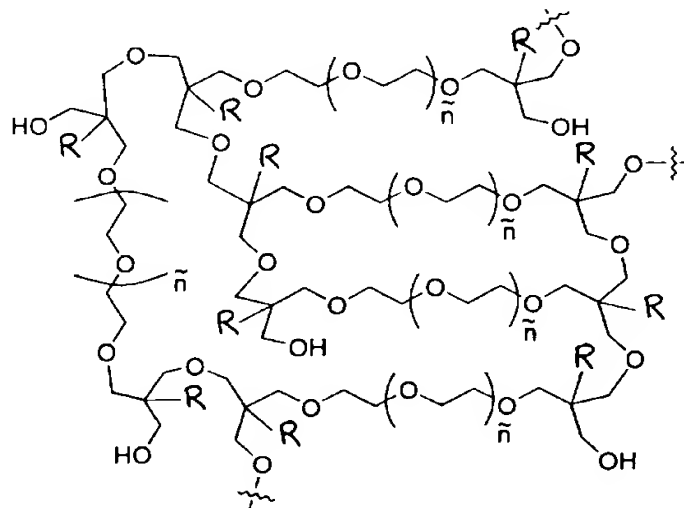


10

where $\bar{n} = 6-300$

where R_a and m are as defined in claim 1.

13. A cross linked polymer according to claim 11 wherein the macromonomer has the
 15 structure claimed in claim 5, the polymerisation is initiated by a cationic catalyst and the structure of the polymer may be represented by the structure:



where $\bar{n} = 6-300$

5

where R is as defined in claim 1.

14. A crosslinked polymer according to claim 11 wherein the macromer used for its preparation has the structure of claim 6 and the per-*O*-acetylated or in other ways temporarily hydroxyl-protected polymer structure analog to the hydroxylated structure of claim 13 is obtained.

15. A cross linked polymer formed by the bulk polymerisation of a macromonomer of claim 3.

15

16. A beaded crosslinked polymer according to claim 12 made by reverse suspension- or spray polymerization

17. A beaded resin according to claim 13 or 14 formed by polymerization of droplets in silicon oil.

18. A beaded resin according to claim 13 or 14 formed by spray polymerization in a
5 hot inert gas.

19. The use of polymers prepared according to claim 11 as supports for organic synthesis.

10 20. The use of polymers prepared according to claim 11 as supports for solid phase enzyme reactions.

21. The use of polymers prepared according to claim 11 as supports for synthesis of peptides, DNA, RNA and oligosaccharides.

15

22. The use of polymers prepared according to claim 11 as supports for peptide-, protein-, DNA- or RNA-ligation.

23. The use of polymers prepared according to claim 11 for chromatographic
20 separations.

24. The use of polymers prepared according to claim 11 for affinity purification.

25. The use of polymers prepared according to claim 11 for protein immobilisation
25

26. The use of polymers according to claim 20 in which the enzyme interact with a substrate or an inhibitor linked to the support.

27. The use of polymers according to claim 11 in which the use involves release of a
5 drug bound to the solid support.

28. Release of a drug according to claim 27 where the release is mediated by an enzyme.

10 29. The use of polymers according to claim 11 for solid phase magic angle spinning NMR-spectroscopy.

30. The use of polymers according to claim 11 for combinatorial chemistry.

15

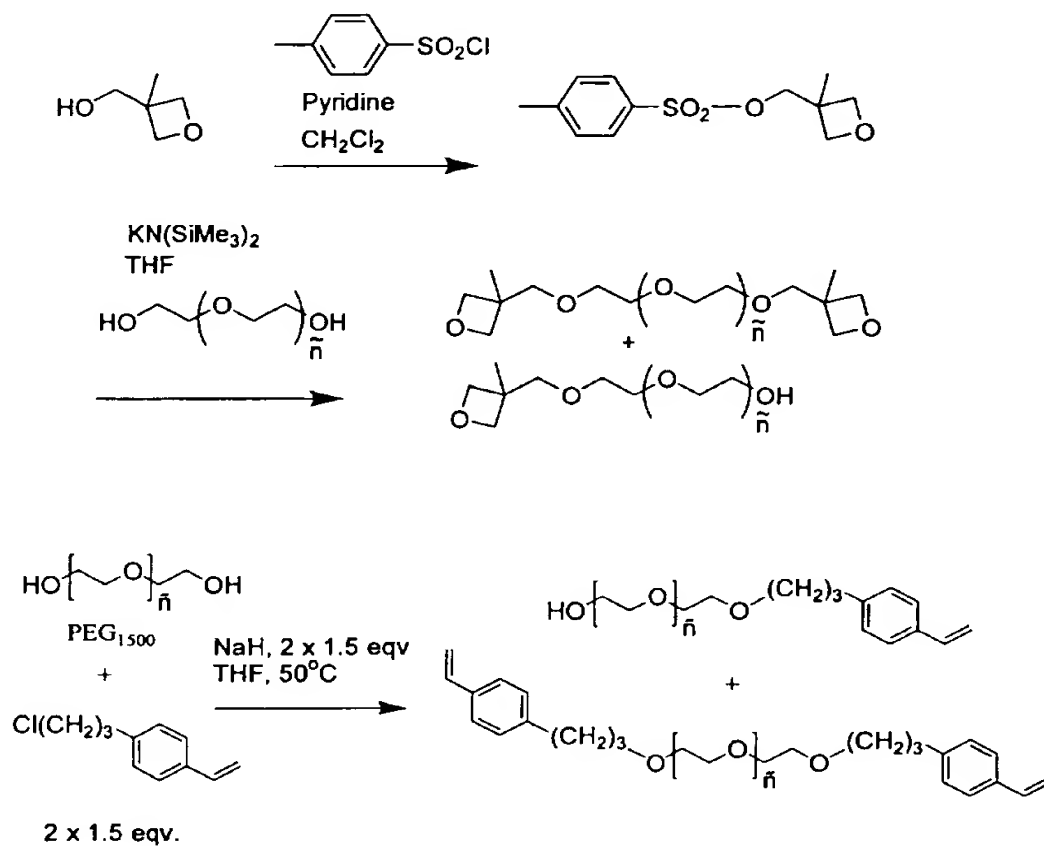


Figure 1 is a schematic representation of the reactions involved in the preparation of vinylphenylalkyl ether capped polyethylene glycol and oxetane capped polyethylene glycol macromonomers.

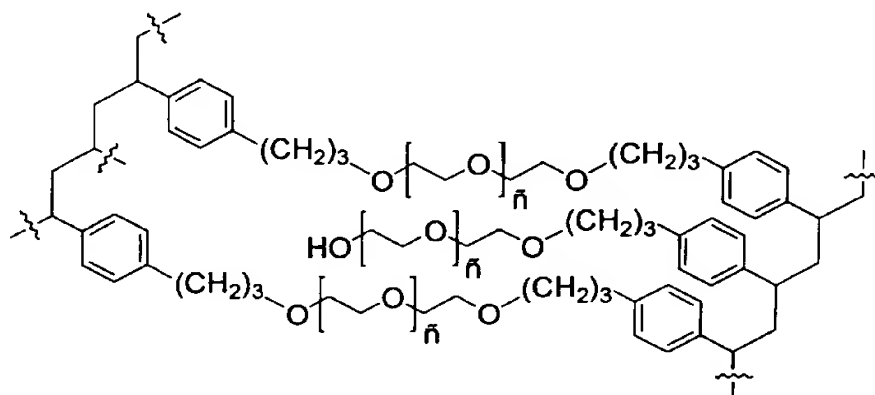
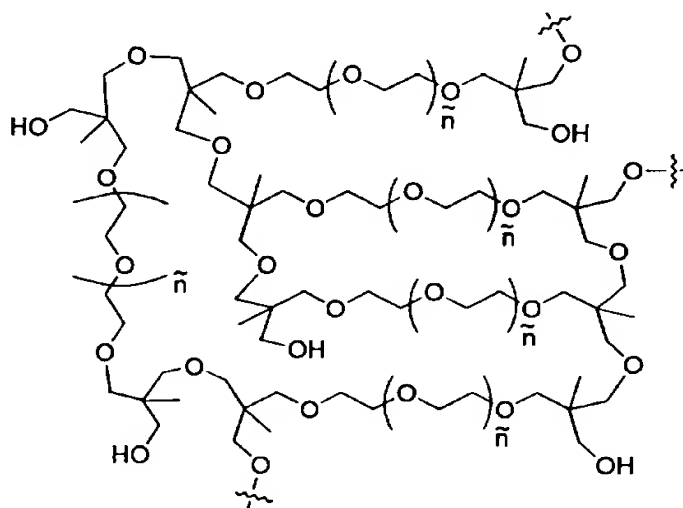


Figure 2 is a representation of the cross-linked resin obtained by polymerisation of vinylphenylalkyl ether capped polyethylene glycol.



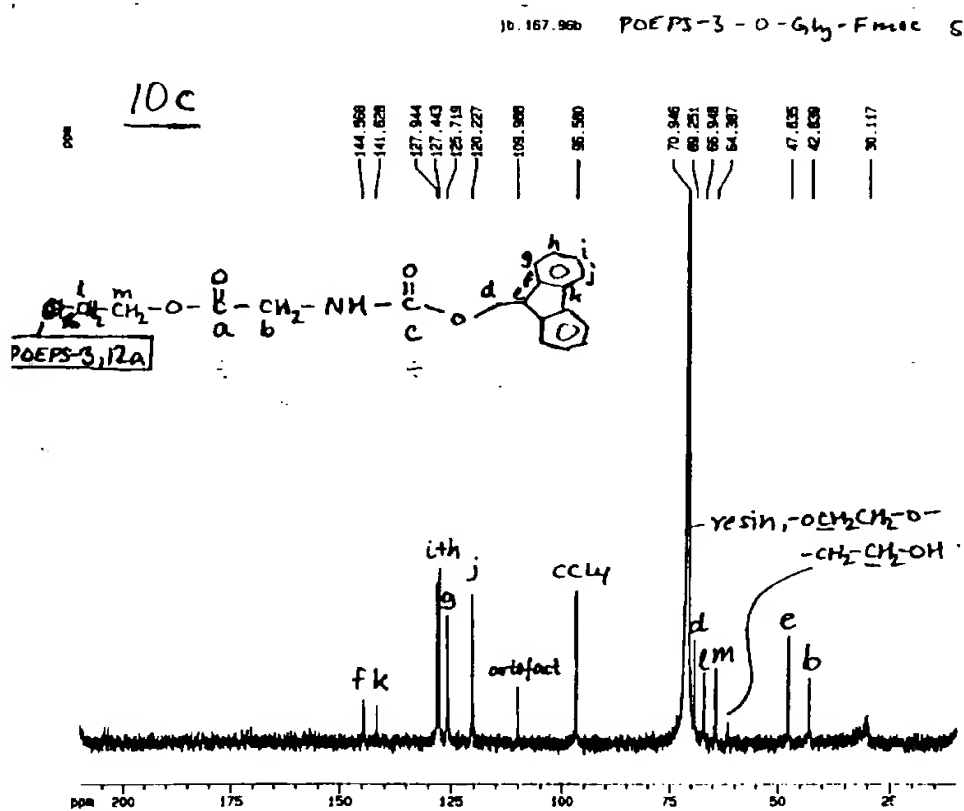


Figure 4 is a gel phase ^{13}C NMR trace of the cross-linked polymer of Figure 2 derivatized by Fmoc-Gly.

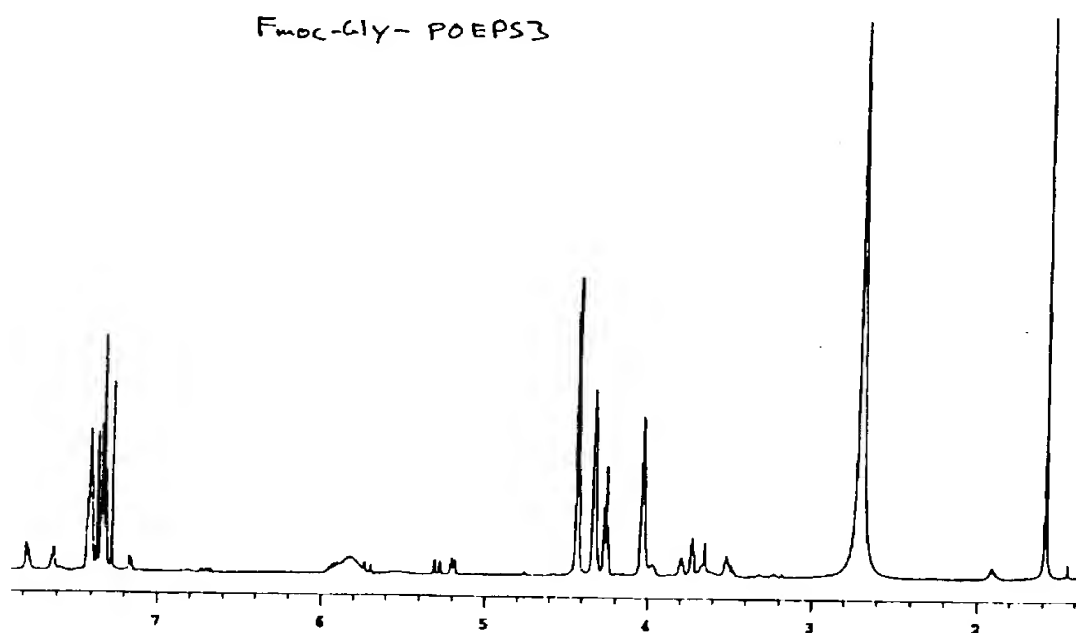


Figure 5 is a magic angle spinning solid phase ^1H -NMR trace with selective irradiation at 3.67 ppm to suppress the PEG signal of the cross-linked polymer of Figure 2 after acylation with Fmoc-Gly. Resolved spectra were obtained and similar results were obtained with the resin in Figure 3 in MAS solid phase ^1H -NMR spectroscopy.

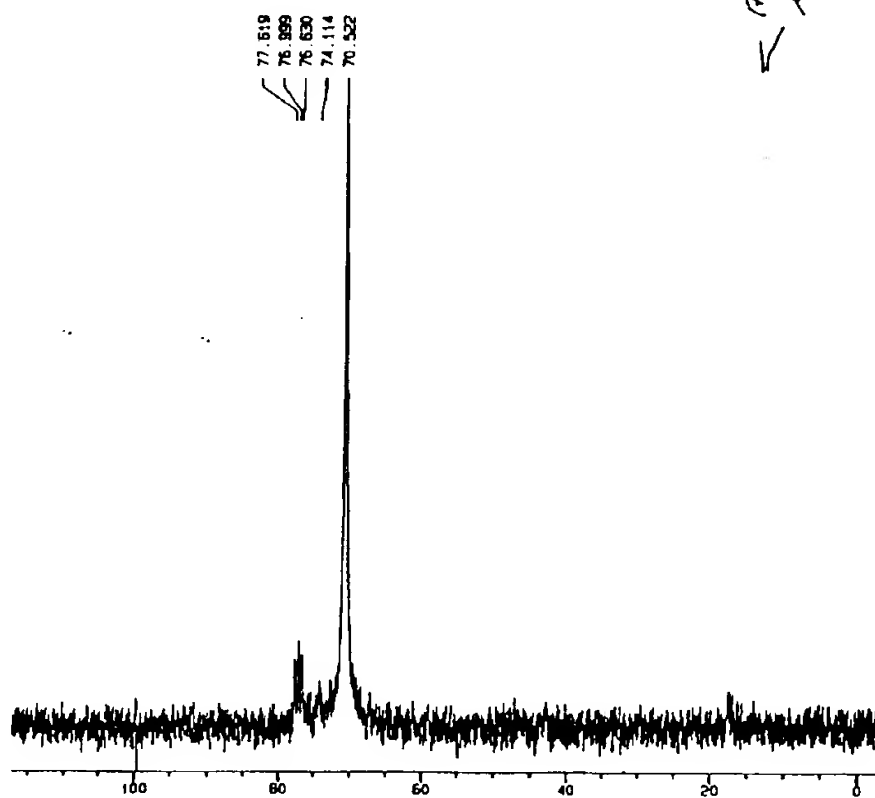


Figure 6 is a gel phase ^{13}C -NMR trace of the cross-linked polymer of Figure 3.

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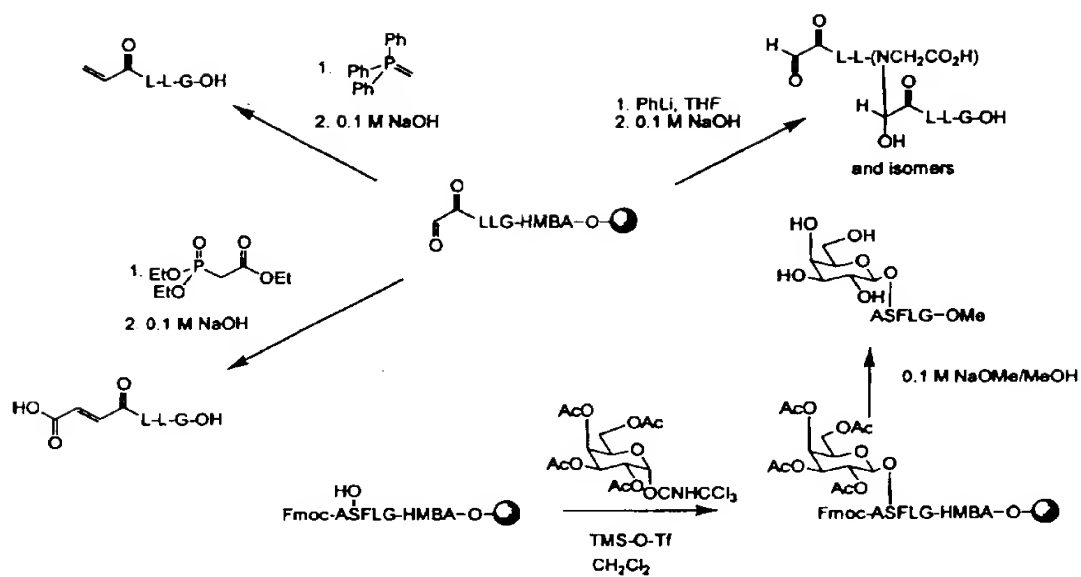
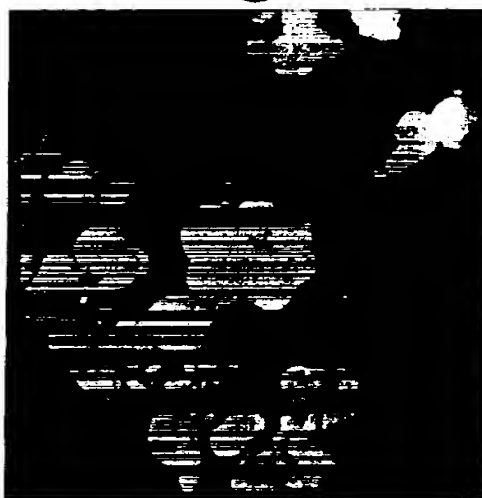


Figure 7 Shows organic reactions which have been successful on resin prepared by polymerization of 3-methyloxetan-3-ylmethyl derivatised macromonomers



Before enzyme addition.



1 h enzyme reaction

Figure 8 Illustrates a solid phase enzyme assay in which a fluorescence quenched substrate bound to a resin prepared from vinylphenylpropyl-PEG macromonomers is cleaved for 1 h by subtilisin Carlsberg migrating through the polymer network. The same result was obtained with the SPOCC polymer.

